Geophysical Research Abstracts, Vol. 7, 02008, 2005
SRef-ID: 1607-7962/gra/EGU05-A-02008

Effects of spatial discretization in ice sheet modeling

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We assess a one- and two-dimensional, vertically integrated ice flow model for its numerical properties with respect to ice sheet evolution on a sloping bed. We discuss the influence of initial conditions and individual model parameters on the model's numerical behavior, while varying spatial discretizations. The focus is not on resolving power of fine structures, but on the global behavior of large, smooth ice sheets. The modeling results suffer badly from numerical problems due to inaccuracies in the calculation of the surface gradient. In cases where the mass balance parameterization is a function of height, this results in modeled ice sheets having a strong dependence on grid cell size. The numerical errors are small for each single time step, but increase nonlinearly over time causing the model's numerical behavior to be a strong function of initial conditions, local geometry and climate. We conclude that the widely used grid cell spacing of 20 kilometers is too coarse. We propose a new method for the calculation of the surface gradient, which improves the results significantly. However, this does not solve the problem entirely. Therefore, we recommend the investigation of the numerical behavior of ice flow models with respect to spatial discretization for each specific case.